A SYSTEM DYNAMICS MODEL IN CLOSED-LOOP SUPPLY CHAIN BY ASSESSING SUSTAINABILITY

SAEED RAHIMPOUR GOLROUDBARY

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Universiti Teknologi Malaysia

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I dedicated this thesis to my beloved Mother, Father, and Brothers for their endless supports and encouragements, my friend who has been great source of motivation and inspiration.

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ABSTRACT

Since the 20th century, the global economic system has been developing rapidly. At the same time, discretional exploitation of natural resources caused some major problems such as global ecological damage, resources wastage and shortage and environmental pollution. On the other hand, remanufacturing of used merchandise and bringing them back to the market provides not only the environmental and customer benefits to Original Equipment Manufactures (OEMs) but it also cuts back their production cost. In sum, there is now a well-recognized need for achieving overall sustainability in industrial activities arising due to several established and emerging causes: diminishing non-renewable resources, stricter regulations related to environment and occupational safety/health, increasing consumer preference for environmentally-friendly products. Owing to the revolution in sustainable and green manufacturing the production planning and network design of Closed Loop Supply Chain (CLSC) concept has caught the attention of researchers and managers. The goal of this project is to provide an extensive and detailed review of investigations related to applying System Dynamics (SD) in the sustainability of closed loop supply chain. The final result proved that it can be achieved to sustainability by SD method in CLSC. This project considered customer satisfaction and Green Image factor (GIF) as factors which encompass two dimensions of sustainability to make a sustainable CLSC in manufacturing. In this project, a CLSC system is simulated by focusing on two main factors, which are customer satisfaction and green image factor to help the company to have corrective and preventive action to comply with ISO 9001 and ISO 14001. The impacts of shipment time and delivery time on the demand backlog level and customer satisfaction degree are examined first, and then the effects of collector centre is investigated to improve the GIF level by increasing the amount of return used products.

ABSTRAK

Sejak abad ke-20, sistem ekonomi global telah membangun dengan pesat. Pada masa yang sama, eksploitasi sumber asli menjadi tidak terbatas disebabkan beberapa masalah utama seperti kerosakan ekologi global, pembaziran sumber, kekurangan dan pencemaran alam sekitar. Sebaliknya, pembuatan semula barangan yang digunakan serta mengembalikan ia kembali ke pasaran bukan sahaja memberi faedah kepada alam sekitar, pelanggan dan *Kelengkapan Asli Pembuatan* (OEM) tetapi ia juga mengurangkan kembali kos pengeluaran.Kesimpulannya, kini terdapat keperluan yang diiktiraf bagi mencapai kelestarian secara menyeluruh di dalam aktiviti perindustrian kerana beberapa sebab yang baru muncul; mengurangkan sumber yang tidak boleh diperbaharui, menguatkuasakan peraturan yang lebih ketat yang berkaitan dengan alam sekitar dan keselamatan pekerjaan / kesihatan, serta meningkatkan pilihan pengguna untuk produk mesra alam.Oleh kerana revolusi kelestarian dan ‘pembuatan hijau’ perancangan pengeluaran dan reka bentuk *rangkaian bekalan rintangan tertutup* (CLSC) telah menarik perhatian penyelidik dan pengurus. Matlamat projek ini adalah untuk menyediakan kajian yang menyeluruh dan penyiasatan terperinci berkaitan dengan permohonan Sistem Dinamik (SD) dalam kelestarian rantaian bekalan rintangan tertutup. Keputusan akhir membuktikan bahawa kelestarian boleh dicapai melalui kaedah SD dalam CLSC. Projek ini menganggap kepuasan pelanggan dan faktor Imej Hijau (GIF) sebagai faktor yang merangkumi dua dimensi lestari untuk mencapai kelestarian CLSC di dalam pembuatan. Dalam projek ini, sistem CLSC telah disimulasi dengan memberi tumpuan kepada dua faktor utama iaitu kepuasan pelanggan dan faktor imej hijau untuk membantu syarikat mempunyai tindakan pembetulan dan pencegahan yang mematuhi ISO 9001 dan ISO 14001. Kesan masa penghantaran pada peringkat permintaan tunggakan dan tahap kepuasan pelanggan paling awal diteliti, seterusnya kesan pengumpulan pusat disiasat untuk memperbaiki tahap GIF dengan meningkatkan jumlah produk pulangan yang digunakan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter at first background of study is explained based on the knowledge provided through studying previous works. Next the problem statement, objective, scope and the significance of the study is presented. Organization of the study and the conclusion are the two last parts of this chapter.

1.2 Background of Problem

Mass consumption and indiscriminate disposal habits have revealed our planet's limitations (Gupta, 1995; Umeda, Nonomura, & Tomiyama, 2000). Also, industrial economies have generated tremendous amounts of waste; available landfills are filling up and new one cannot be located (Madu, Kuei, & Madu, 2002).

A supply chain is traditionally considered as a line, starting with the movement of goods from suppliers to manufacturers, and going ahead with wholesalers, retailers, and finally reaching consumers through these distribution channels. Nowadays, by enhancing the interaction between the ends of this line, supply chain designs tend to become circular to form the closed loop rather than being linear. Hence, complex industrial relationships prove the existence of material flows not only downstream but also upstream during the production, distribution, and consumption stages (Cruz-Rivera and Ertel 2009, Özkır, V., & Başlıgıl, H. 2012).

Also, every supply-chain activity, including the reverse chain, generates emissions, pollution, and waste via diverse processes in the environmental chain, and eventually has an (negative) impact on natural resources. As these natural resources are necessary inputs for the supply chain, it is essential for firms to include environmental criteria in both their product design and supply-chain design, and for countries to develop environmental policies to maintain the balance of nature and the continuity of supply chains. Reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal which covers all manufacturing and logistics activities including re-use, remanufacturing, recycling, and managing hazardous materials (Tibben-Lembke and Rogers 2002). Attempts for managing both forward and reverse flow in a supply chain are examined in the context of a closed loop supply chain (CLSC). CLSC design studies aim to establish an effective and efficient system for any type of material flow in the supply chain regarding environmental and economic concerns. The main challenge in CLSC design is the closeness of the chain, which can be measured by the amount of waste that it generates. In other words, the supply chain gets closer if and only if it generates less waste than before (Özkır, V., & Başlıgıl, H., 2012).

From other perspective, in today's competitive market, customer satisfaction has been one of the important focused areas in every organization. And also because of the restrictions from the government in bearing responsibility regarding proper disposal, forced the manufacturers to concentrate on CLSC system and reducing the cost. A systematic review system and optimum period of reviewing will help in achieving customer satisfaction in an effective way. Over the last decade or so, closed loop supply chain management has emerged as a key area of research among the practitioners of operations research. A lot of research is being carried out to make the CLSC more efficient and economic. The smooth and efficient functioning of a business involves the smooth and efficient functioning of the principal areas of the supply chain (Poles & Cheong, 2011). In addition, due to the social, economical and environmental concerns, CLSC practice has been gaining growing interest among researchers and practitioners of operations and SCM over the last decade.

In this study the focus is on the study of customer satisfaction factors, Green Image factors (GIF) in the CLSC system. In this project, a system dynamics (SD) model is developed to cope with the dynamics of CLSC. It covers all three dimensions of sustainability by considering social factors which leads to customer satisfaction, minimize the environmental issues and minimize total cost.

Since 20th century, global economy is developing rapidly. At the same time, discretional exploitation for natural resources caused some major problems, such as global ecological damage, resources wastage and shortage, environmental pollution and so forth. (Du, L., Wu, J., & Hu, F., 2009)

In other hand, remanufacturing of used products and bringing them back to the market provides not only the environmental and customer benefits to OEMs but it also reduces their production cost (Lee, Gen, and Rhee 2009). Compared with normal production, manufacturers can save about 40–60% of the cost while paying for only 20% of the manufacturing effort (Dowlatshahi 2000). Kim, Raichur, and Skerlos (2008) demonstrated that a remanufactured product uses less than 20% of the materials, 16% of the energy and releases only 35% of the greenhouse gas emissions of those released in the process of producing a new product. (Pishvaee, M. S., & Razmi, J. ,2012).

There is now a well recognized need for achieving overall sustainability in industrial activities, arising due to several established and emerging causes: diminishing non-renewable resources, stricter regulations related to environment and occupational safety/health, increasing consumer preference for environmentally-friendly products, etc.(Jayal, A. D., Badurdeen, F., Dillon Jr, O. W., & Jawahir, I. S. , 2010).

In many countries, manufacturers are required to take the responsibility for the whole process of product life cycle, especially for recycling and reuse treatment of waste products. As the limitations of traditional supply chain model are increasingly exposed, a closed-loop supply chain that is on a basis of the remanufacturing system becomes a more effective way for coordinating development

of economy and environment, and has been paid a great attention by Industry and Academia. Closed-loop supply chain based on remanufacturing system usually include the forward supply chain, and the reverse logistics for taking waste products back to the producer from consumer, and the forward logistics for delivering remanufactured products to consumer from the producer (Du, L., Wu, J., & Hu, F. ,2009,). Also, the facets of Sustainable Supply Chain Management (SSCM) with three critical dimensions are CLSC; green supply chain (GSC) and reverse logistics (Subramanian, P., Ramkumar, N., Narendran, T. T., & Ganesh, K., 2012).

1.3 Problem Statement

Owing to the revolution in sustainable and green manufacturing the production planning and network design of closed loop supply chain concept has got the attention of researchers and managers (Jindal, A., & Sangwan, K. S., 2013). In many industries, original equipment manufacturers (OEMs) are looking for efficient ways to integrate reverse logistics into their supply chains, to recover economic value from returned products and to reduce disposal costs (Autry 2005; Realff, Ammons, and New 2000). Pishvaee, M. S., & Razmi, J. (2012) state environmental issues have become a critical topic in recent years.

In addition, by considering all three dimensions of sustainability, the significant of social factors is stated by Egilmez, G. & Tatari, O. (2012), and emphasized on environmental factors by Carter and Gennings (2004) and Porter and Kramer (2006). Also, economic factors are important to consider (Georgiadis, P. & Besiou, U. 2008 ; Chiou, C. 2010).

Meade et al. (2007) categorize the main reason of increasing attention and investment in reverse flow design into two main categories: environmental reasons and business reasons. The first category includes the effect of used product on environment and environmental legislation. The second category concerns the economic benefits of using recovered products and companies policies for improving their customer satisfaction (Mirakhorli, A., 2010).

Sustainable supply chain management must integrate environment, economic, and social features of industrial in that setting. The necessity of promoting the design and managing of sustainable supply chain is very obvious because of lack of research about customer satisfaction and environmental factor (Jayal, A. D., et al. 2010). According to Georgiadis, P., & Besiou, M. (2008) a dynamic and full of feedbacks system can be modeled by SD which is an appropriate modelling and analysis tool.

Finally, Increased waste and reduce customer satisfaction in CLSC due to the internal and external factors impact by SD approach have not been covered enough by researchers. Therefore, there is a need to give a special attention to this specific area of the SC.

1.4 Objectives

The purpose of this study is to consider social factors that leads to customer satisfaction, emphasize on minimize the environmental issues by understanding system behaviour, and minimize total cost. This will be carried out under the following objectives:

1. To develop a system dynamic model for assessing sustainability in CLSC.
2. To establish customer satisfaction factor as the social factor in CLSC.
3. To establish Green Image Factor (GIF) as the environmental factor in CLSC.

1.5 Research Question

The following questions will be addressed by this research:

1. What is the system dynamic model for assessing sustainability in CLSC on a recyclable product?
2. How to establish customer satisfaction factor as the social factor in CLSC?

3. How to establish GIF as the environmental factor in CLSC?

1.6 Significance of Study

This study provides a perfect meaning of sustainability in a closed loop supply chain. This project is able to support people to recognize the importance of variations by SD approach. This technique may also support people to make improved selections linked to CLSC and Sustainability responsibilities. The result of project clues to a choice that consequence in actions affecting the state of the system. Such an understanding may only be achieved by considering and exploring interactions among a number of related social, economic, environmental, managerial, regulatory, and lifestyle factors. Finally, the analyses and results of this study may be helpful for future insight into closed loop supply chain operations.

1.7 Aim of Study

The main goal of this study is categorized as:

- To achieve system behaviour at an integrated level
- To reduce the cost
- To achieve customer satisfaction
- To reduce environmental issues
- To have more efficient and economic system
- To forecast the development of a dynamic and complex waste management system
- To reduce the volume of waste
- To reduce risk
- To overcome dynamic nature
- To evaluate the effect of environmental issues on long-term decision
- To achieve green image, green consumerism

- To achieve economically and ecologically feasible
- To use better recycling technologies, optimistic growth in recycling rates, and the use of market incentive for recycling
- To consider integrated perspective and renewable energies

1.8 Scope and Limitation of Study

This research will focus on two factors which are GIF, by measuring collecting rate and recycling rate, and customer's satisfaction, by measuring the demand level on the policy of a closed-loop supply chain with recycling activities on a selected recyclable product in ON Semiconductor company as a case study by using one of the high level graphical SD programs such as Vensim®, i-think® and Powersim®.

1.9 Operational Definition of Terms

SCM: Supply chain management (SCM) is the management of material and information flows both in and between facilities, such as vendors, manufacturing and assembly plants, and distribution centres. (Cho & Lee, 2013)

SD: System Dynamics is a computer-aided approach for analysing and solving complex problems with a focus on policy analysis and design. (Angerhofer & Angelides, 2000)

CLSC: Today we define closed-loop supply chain management as the design, control and operation of a system to maximize value creation over the entire life-cycle of a product with dynamic recovery of value from different types and volumes of returns over time.(Guide & Van Wassenhove, 2009)

1.10 Organization of Study

This research proposal consists of three chapters. Chapter 1 begins with the introduction, followed by the research background, the statement of the problem, research objective, research questions, the scope and limitations of the study, operational definition of terms, and the organization of the study.

Chapter 2 extensively discusses the literature review related to sustainability, SD, Supply chain as well as the various factors that affect system behaviour on long term, the research gap of this project is also presented followed by a summary of the chapter.

Chapter 3 is the research methodology. It begins with an introduction to the chapter, followed by the research design, research framework of the study, research method, the company profile, SD modelling process, and the CLSC pre-model.

Chapter 4 is model construction. In this chapter, a brief introduction about Vensim PLE v5.4b software, causal loop diagram and Stock and Flow diagram are presented. Then mathematics formulations of model are described. Next, data collection and distribution fitting will be presented. Finally, verification and validation of model will be shown at the end of this chapter.

Chapter 5 shows the result of current CLSC model and the Improvement state of the CLSC of the company. Then, the difference between current and improvement CLSC are compared based on different results. Finally, a summary of this study and some possible future directions of research are presented.

1.11 Conclusion

This chapter provides a structure for the study. The background presented in this chapter gives sufficient content to understand the intention of the study. In

addition, the significance and effect of this study on solving the existing problem is illustrated. It is expected that conducting this study will be successful to deal with dynamic behavior of supply chain and bring beneficial results for CLSC by considering different factors of system.

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